instruction manual

EVAL. INSTR. LAB.

INSTRUCTION MANUAL

MODEL 5800 SERIES
NUMERICAL CONTROLLER

Beckman®

Berkeley Division

EVAL. INSTR. LAB.

INSTRUCTION MANUAL

MODEL 5800 SERIES
NUMERICAL CONTROLLER

Model No. _____

Serial No. _____

NOTE

If model number is followed by one or more letters, the instrument covered by this manual has been modified. See section on modifications.

BECKMAN/ Berkeley Division
Richmond, California

July 1959

WARRANTY

Instruments sold by Berkeley Division, Beckman Instruments, Inc., (hereafter called "the Company") are warranted only as stated below.

Subject to the exceptions and upon the conditions specified below, the Company agrees to correct, either by repair, or, at its election, by replacement, any defect of material or workmanship which develops within one year after delivery of the instrument to the original purchaser by the Company or by an authorized representative, provided that investigation and factory inspection by the Company discloses that such defect developed under normal and proper use.

The exceptions and conditions mentioned above are the following:

(a) Some components and accessories by their nature are not intended to, and will not, function one year. If any such component or accessory manufactured by the Company and part of the item sold fails to give reasonable service for a reasonable period of time, the Company will, at its election, replace or repair such component or accessory. What constitutes reasonable service and what constitutes a reasonable period of time shall be determined solely by the Company after the Company is in posession of all the facts concerning operating conditions and other pertinent factors and after such component or accessory has been returned to the Company, transportation prepaid.

(b) All instruments claimed defective must be returned to the Company, transportation charges prepaid, and will be returned to the customer with the transportation charges collect, unless the item is found to be defective in which case the Company will pay all transportation charges.

(c) The Company makes no warranty concerning components or accessories not manufactured by it, such as tubes, fuses, batteries, etc. However, in the event of the failure of any component or accessory not manufactured by the Company, the Company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.

(d) Except as stated above, the Company makes no warranty, express or implied (either in fact or by operation of law), statutory or otherwise; and, except to the extent stated above, the Company shall have no liability under any warranty, express or implied (either in fact or by operation of law), statutory or otherwise.

(e) The Company expressly disclaims any liability to its customers, dealers, and to users of its products, and to any other person or persons for consequential damages of any kind and from any cause whatsoever arising out of or in any way connected with the manufacture, sale, repair, replacement of, or arising out of or in any way connected with the use of any of its products.

(f) Representations and warranties made by any person, including representatives of the Company, which are inconsistent or in conflict with the terms of this warranty (including but not limited to the limitation of the liability of the Company as set forth above) shall not be binding upon the Company unless reduced to writing and approved by an officer of the Company.

(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate. Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, Berkeley division of Beckman Instruments, Inc., Richmond 4, California.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

Berkeley reserves the right to make changes in design at any time without incurring any obligation to modify equipment previously purchased to conform to subsequent design changes.

BERKELEY DIVISION
BECKMAN INSTRUMENTS, INC.

MANUAL REVISION

Please check serial number prefix on nameplate of instrument to see which of these changes apply.

MODEL 5800 SERIES

Serial Prefix

21- Change transistors Q101, Q102, and Q201 to 2N1420

Change diodes CR201 through CR205 to Beckman type 404593. (1-62)

Schematic Diagram, Drawing No. 5800 C 1

The values of resistors R106 and R122 should be 5.6K and 330 ohms, respectively.

21- Register Drive Circuit, Modifications MBD and MC, Drawing No. 5800 A 200

Note** should read

**Modification MC (Count Extension) only, R302 is 10K (4-62)

Beckman

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INTRODUCTION

1.1 GENERAL DESCRIPTION

The 5800 Series Numerical Controller is an electronic counter which produces output signals whenever a preselected count is reached. These signals are available at output terminals, either as contact openings and closures, or as changing DC voltage levels. They can thus be used to control processes automatically or actuate alarms for alerting personnel.

The instrument will count any series of physical events which can be translated into current changes through an input transducer. It will count these events at any rate up to 5000 per second and continually display the accumulated count in digital form on the front panel.

There are nine basic model variations in this series of instruments. Model 5813, 5814 and 5815 are single preset controllers; that is, output control signals can be obtained at any single preselected number of counts. Models 5823, 5824 and 5825 are dual preset controllers and provide control signals at any two preselected counts. Models 5803, 5804 and 5805 perform only the counting function and do not provide any control signals. The last digit in the model number denotes the number of digits that the instrument displays and hence its count capacity (see Section 1.2, "Technical Characteristics"). The next to last digit denotes the number of control points.

Intended mainly for industrial applications, the Numerical Controller has been designed to give continuous, trouble-free service in a factory type of environment. For maximum reliability, magnetic and solid state components have been used throughout the unit wherever possible. Since these components generate so little heat that no ventilation is needed, the instrument has been completely enclosed in a protective dustproof enclosure.

The input to the controller can come from either a Model 480 Magnetic Proximity Pickup, or any of the other transducers manufactured by Beckman/Berkeley. Besides operating with these input devices, the instrument will also register events represented by contact closures.

1.2 TECHNICAL CHARACTERISTICS

Counting Rate

Zero to 5000 counts per second.

Count Capacity

Models 5803, 5813 and 5823:	999.
Models 5804, 5814 and 5824:	9,999.
Models 5805, 5815 and 5825:	99,999.

Accuracy

Absolute

Input Sensitivity

0.5 volts rms into 10K ohms
(Bias current of +250μa required at INPUT 2)

Outputs

At each preset count: a voltage pulse, and a DPDT contact movement. Contact movement may be either momentary or sustained.

Reset

From pushbutton on panel or external contact closure.

Power Required

117V AC, 60 cps; 25 watts.

Dimensions

8 in. wide, 11 in. high, 9 in. deep.

Weight

10 lbs.

1.3 APPLICATIONS

The 5800 Series Controller can be used to control a wide variety of industrial processes which fall into the following general classes: Those which require the counting of discrete objects as in sorting and packaging; those in which the repetitions of a given operation, such as the closing of a switch, are counted; and, finally, those processes in which the revolutions of a rotating shaft or the reciprocations of a machine member are counted. Included in the last category are all operations, such as cutting to length, in which linear movement can be represented by a shaft rotation.

Winding electric coils is a typical operation which may be controlled by this equipment. In this case the input to the controller is the output of a magnetic pickup. A small permanent magnet is attached to the rotating shaft and the pickup is set up so that it will produce an output signal each time the magnet passes it. Thus, as the coil form rotates, adding turns of wire, the output signals from the pickup will trigger counts on the controller. At the first preset count (count "A"), "A" relay contacts add resistance in series with the motor which is turning the coil form, causing the motor to slow down. At the second preset count, opening "B" relay contacts disconnect power from the motor and apply a brake. In this way most of the coil can be wound at high speed to save time, then slowed to enable stopping at a precise number of turns without undue strain on equipment.

2.1 INSTALLATION

2.1.1 Mounting the Instrument

Normally, the controller is mounted against any convenient vertical surface using the mounting holes in the rear of the unit. It will operate well at any room temperature tolerable to personnel. Although the unit is not particularly affected by stray magnetic fields, location in any strong magnetic field, such as might exist near a large electric motor or power transformer, should be avoided.

After the controller has been mounted, input and output, as well as AC power connections, must be made before it is put into operation. (Note: no output connections are required for Models 5803, 5804 and 5805.) All electrical connections are made on the terminal strips exposed at the sides of the unit when the cover is removed. One hole on each side of the cabinet near the back permits the use of BX cable or electrical conduit carrying the connecting wires. The two leads of a 117 volt AC line are connected to the terminals marked LINE 1 and LINE 2.

NOTE: Any AC line voltage which fluctuates beyond the limits of 105 to 130 volts may cause damage to components in the controller. It is recommended, therefore, that in all such cases a Sola type 23-13 stabilizing transformer be used between the power source and the line terminals of the instrument.

2.1.2 Input Connections

All input connections are made on the upper terminal strip at the left of the instrument. If a Model 480 Magnetic Proximity Pickup is being used as the input transducer, the leads from the pickup should be connected to the terminals labeled INPUT 1 and GND. All other Beckman/Berkeley transducers should be connected to the terminals labeled INPUT 2 and GND. If an external contact closure is used to trigger counts in the instrument, the input leads should likewise be connected to the INPUT 2 and GND terminals.

Leads from external contacts used to reset the instrument should be connected to the terminals marked EXT. RESET and GND.

2.1.3 Output Connections

The output signals produced when a preset count is reached, appear at the numbered terminals on the corresponding side of the instrument (i.e., left side for "A" preset and right side for "B" preset). These output signals consist of the following: A change in voltage level of -50 volts at terminal 7 to ground (terminal 8), contact closures between terminals 1-6 and 3-4, and contact openings between terminals 5-6 and 2-3. Once they occur, these outputs are sustained until the unit is reset. Output signals of momentary duration can be obtained by removing resistor R210 (see drawing 5800 C 2) from the circuit. When this is done, the output signals have a duration of about 0.1 second.

NOTE: When resistor R210 is removed, proper output operation depends on the presence of a functioning indicator lamp (I201).

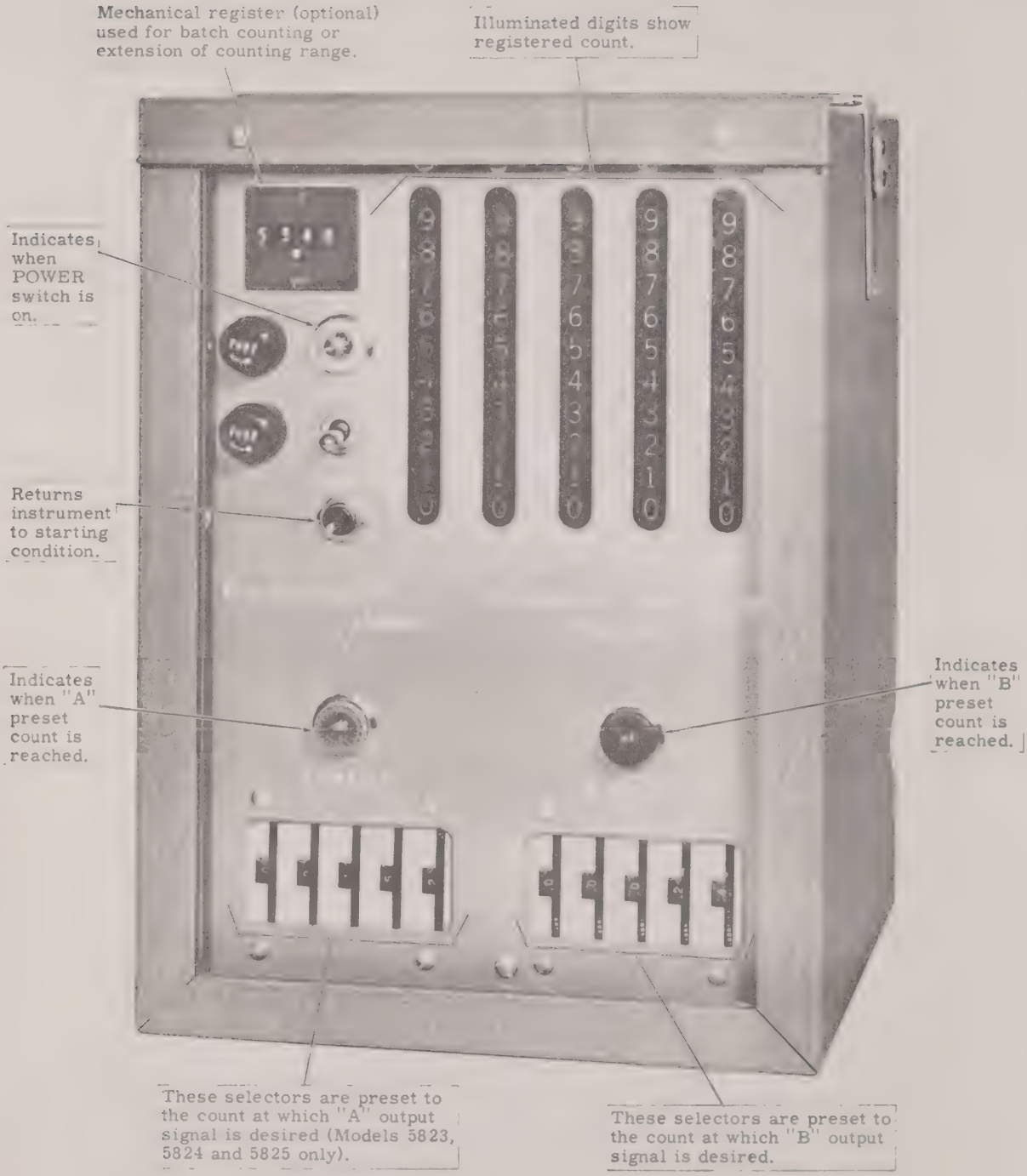

Mechanical register (optional) used for batch counting or extension of counting range.
Illuminated digits show registered count.
Indicates when POWER switch is on.
Returns instrument to starting condition.
Indicates when "A" preset count is reached.
Indicates when "B" preset count is reached.
These selectors are preset to the count at which "A" output signal is desired (Models 5823, 5824 and 5825 only).
These selectors are preset to the count at which "B" output signal is desired.

FIG. 1 OPERATING FEATURES OF NUMERICAL CONTROLLER

2.2 OPERATING PROCEDURE

To put the instrument into operation after all the proper input and output connections have been made (see Section 2.1 "Installation"), only the following steps are necessary:

1) After the instrument has had power applied to it for about 30 seconds turn the POWER switch on. (Note: the vacuum tube filament is energized even with the POWER switch off, as long as AC power is applied to the unit.)

2) Set the two groups of preset selectors to the two counts at which output control signals are required; the A PRESET to the lower, and the B PRESET to the higher count. (Note: The Model 5813, 5814 and 5815 controllers have only a single preset.)

3) Press the RESET button on the front panel so that the instrument reads zero.

The controller will now automatically begin counting as soon as the process being controlled starts. When the first preset count is reached, the A PRESET indicator goes on and the "A" channel output signals are generated, while the instrument continues to count. When the second preset count is reached, the B PRESET indicator goes on and the "B" channel output signals are produced. Ordinarily, these will be used to halt the operation in process, and counting will therefore stop. As soon as the instrument is reset, the control signals are removed and the entire process is then repeated.

2.3 THEORY OF OPERATION

Refer to drawings 5800 C 1 and 5800 C 2.

The input signals applied to the controller drive a Schmitt trigger circuit consisting of transistors Q101 and Q102. This circuit, in turn, provides pulses of suitable size and shape to drive the chain of decimal counting units (DCU's).

The DCU's are connected in cascade so that the first registers the units of the count, the second the tens, the third the hundreds, and so on. The ten output lines from each DCU go to a corresponding ten-position selector switch (S201 through S205). Each of these switches is preset to one of its ten numbered positions. Thus, when the digit indicated by the corresponding DCU is the same as the setting of the switch, a signal from the DCU will go through the switch to the diode "And" Gate (CR201 through CR205). As soon as all of the digits indicated by the DCU's coincide with the respective switch settings, the "And" Gate will produce an output signal. This coincidence signal is then amplified by transistor Q201 and sets the Flip-flop (SR201 and SR202) to its left-hand state. In this state, the Flip-flop generates an output signal which lights the indicator lamp (I201) and energizes the output relay (K201). The relay, in turn, provides the control signals needed for the external operation.

When a reset signal appears, it triggers the Flip-flop to its right-hand state. As a result, the indicator lamp goes out, and the output relay be comes de-energized, thus removing the control signals. This same reset signal also returns the DCU's to a count of zero.

An RF Oscillator generates the carrier supply voltage for all of the satur - able reactors in the instrument. It also provides power for the various bias supplies which generate the DC operating voltages in the unit.

SERVICING

This instrument has been designed for maximum reliability and should rarely need servicing. It is recommended that field maintenance be restricted to the replacement of defective diodes, indicator lamps, and the vacuum tube. If trouble of a more complex nature develops, the instrument should be returned to the factory for repair.

MODIFICATIONS

MODIFICATION MBD, BATCH COUNTING

This modification includes the addition of a four-place mechanical register and register drive circuit as shown on drawing 5800 A 200, as well as the circuit changes described under MODIFICATION MD. The register tallies one count each time the instrument recycles, and thus shows the total number of times the control operation has been repeated.

The mechanical register is reset by pressing the small lever located just below its indicator window. No external reset connections are required for an instrument with this modification.

MODIFICATION MC, COUNT EXTENSION

In this modification, a four-place mechanical register and register drive circuit have been added to the instrument as shown on drawing 5800 A 200. The input to the drive circuit, in this case, comes from the output of the DCU in the most significant digit position. The mechanical register, therefore, tallies one count each time that DCU goes from "9" to "0". It thus extends the count capacity of the instrument by a factor of 10^4.

The mechanical register is reset by pressing the small lever located just below its indicator window.

MODIFICATION MD, AUTOMATIC RECYCLING

This modification consists of the circuit changes shown on drawing 5800 C 300. With these changes, the instrument will automatically recycle whenever the B preset count is reached. The maximum counting rate for recycling without missing counts is 1000 counts per second.

The installation procedure for an instrument with this modification is as described in section 2. 1 of the manual, except that no external reset connections are required.

MODIFICATION MDE, B-BINARY OPERATION

This modification consists of the circuit changes shown on drawing 5800 C 300. With these changes, the instrument operates as follows:

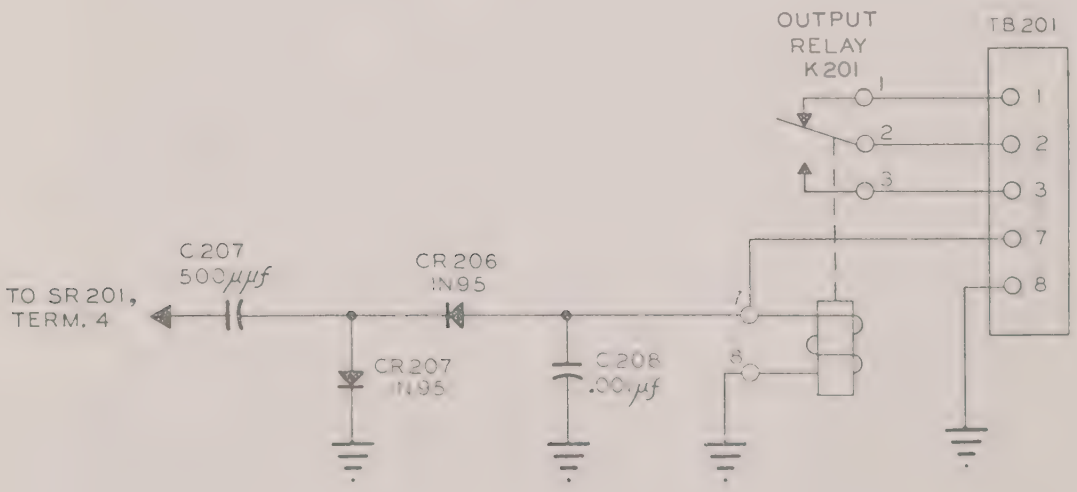
When counting begins, the unit functions as described in section 2. 2 of the manual until the "B" preset count is reached. When the "B" preset count is reached, the "B" channel output relay becomes energized and remains

energized while the counters are automatically reset and begin counting again. On this next cycle the "A" channel output relay functions normally, as before. But this time, when the "B" preset count is reached, the "B" channel relay becomes de-energized and remains de-energized during the next counting cycle. Thus, the instrument continues to recycle automatically, while the "B" channel relay remains in its alternate states during alternate cycles.

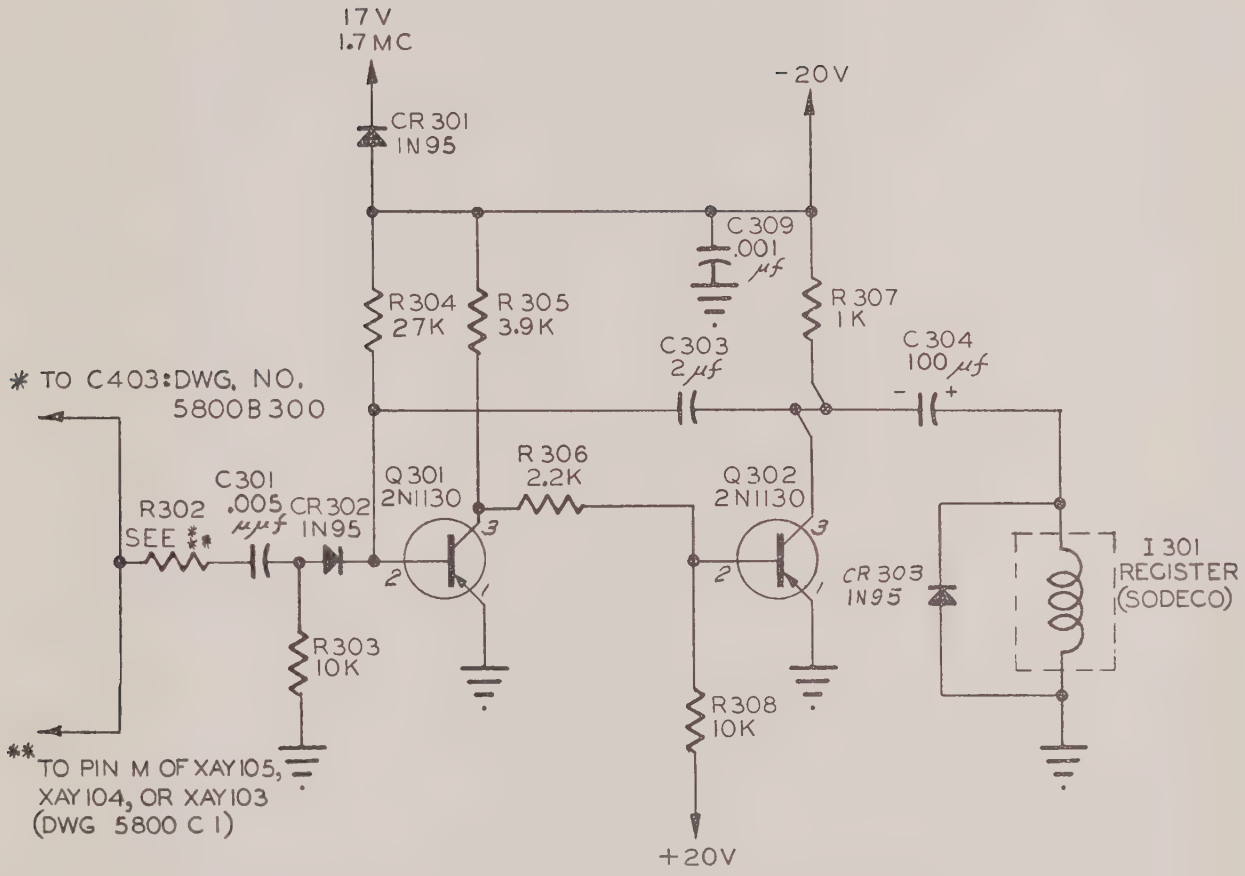
The installation procedure for an instrument with this modification is as described in section 2.1 of the manual, except that no external reset connections are required.

MODIFICATION MA, HIGH SPEED OUTPUT RELAY

In this modification, a relay which operates within 1 millisecond has been substituted for the standard output relay in the Control Module. As shown in the schematic insert for this modification, the relay has one set of form "C" contacts rated at 0.25 amperes at 110 volts DC. In addition, capacitor C207 has been changed from .001μf to 500μμf.



MODIFICATION MA
SCHEMATIC INSERT FOR
CONTROL MODULE (DWG. NO. 5800 C 2)

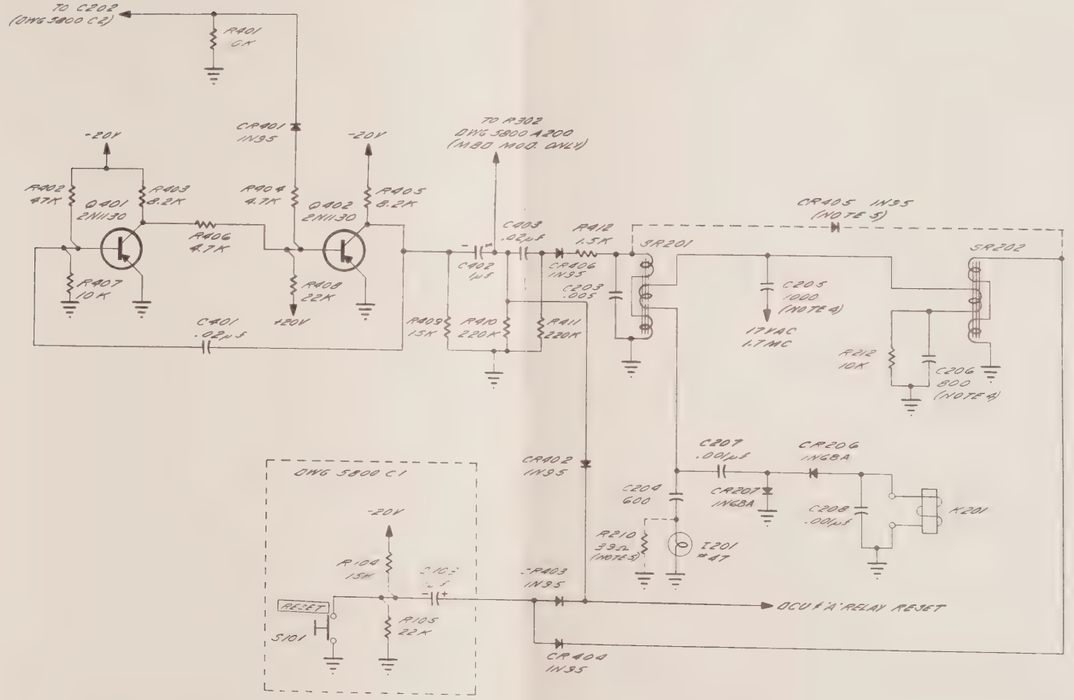


ALL RESISTORS - 1/2 W, 5 %

* MODIFICATION MBD (BATCH COUNTING) ONLY, R302 IS 6.8K

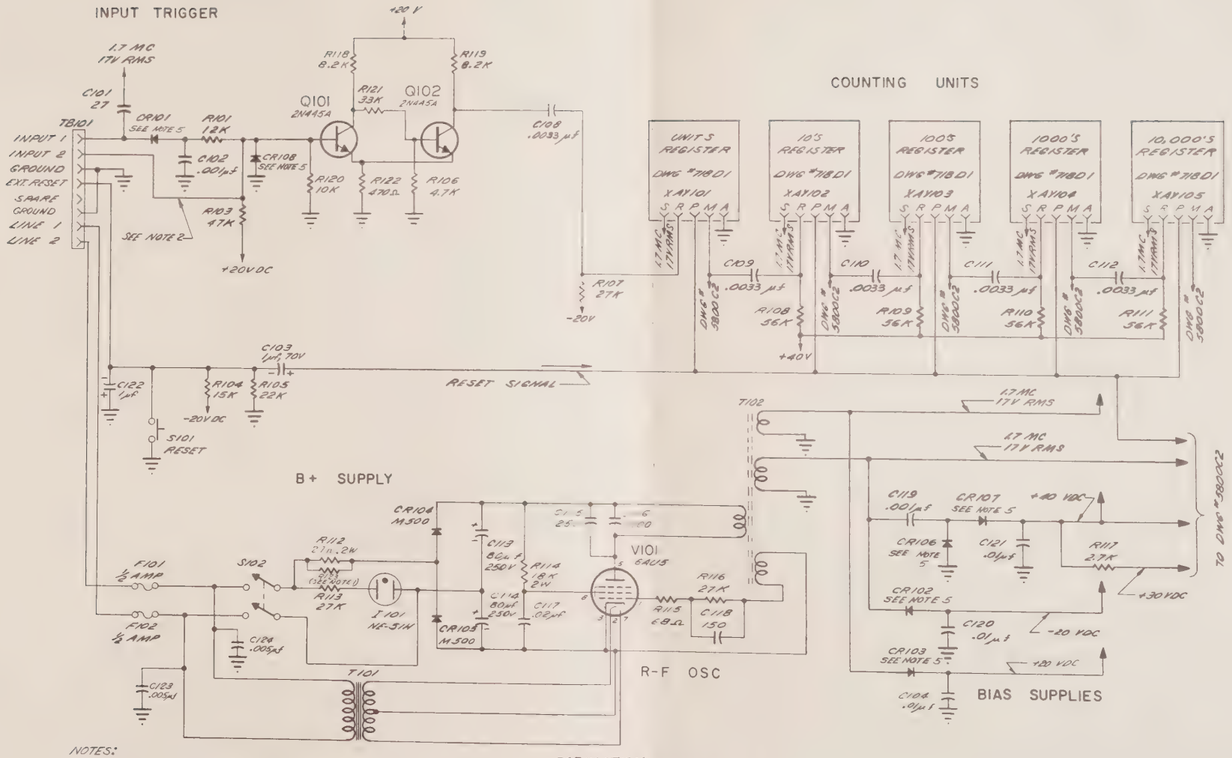
** MODIFICATION MC (COUNT EXTENSION) ONLY, R302 IS 15K

MODEL 5800 SERIES NUMERICAL CONTROLLER
REGISTER DRIVE CIRCUIT
MODIFICATIONS MBD AND MC
DWG. NO. 5800 A 200



NOTES:

1. RESISTORS:
   WATTAGE IS ½ W. EXCEPT AS NOTED.
   TOLERANCE IS 5% EXCEPT AS NOTED.
2. CAPACITORS:
   CAPACITY IS IN MFD. EXCEPT AS NOTED.
3. ALL 400 SERIES COMPONENTS HAVE BEEN ADDED UNDER MODIFICATIONS.
4. VALUES OF C205/C206 CHANGED UNDER MODIFICATION.
5. CR405 / R210 ARE OUT OF CIRCUIT FOR MODIFICATION MD (AUTO RECYCLE). IN CIRCUIT FOR MODIFICATION MDE (S-BINARY OPERATION).



NOTES:

1) VALUE SELECTED AT FACTORY

2) THIS CIRCUIT USED ONLY WITH PHOTO-CELL OR CONTACT CLOSURE INPUTS.

3) RESISTORS: WATTAGE IS 1/2 W. UNLESS NOTED. TOLERANCE IS 5%, UNLESS NOTED.

4) CAPACITORS: CAPACITY IS IN µµF, UNLESS NOTED.

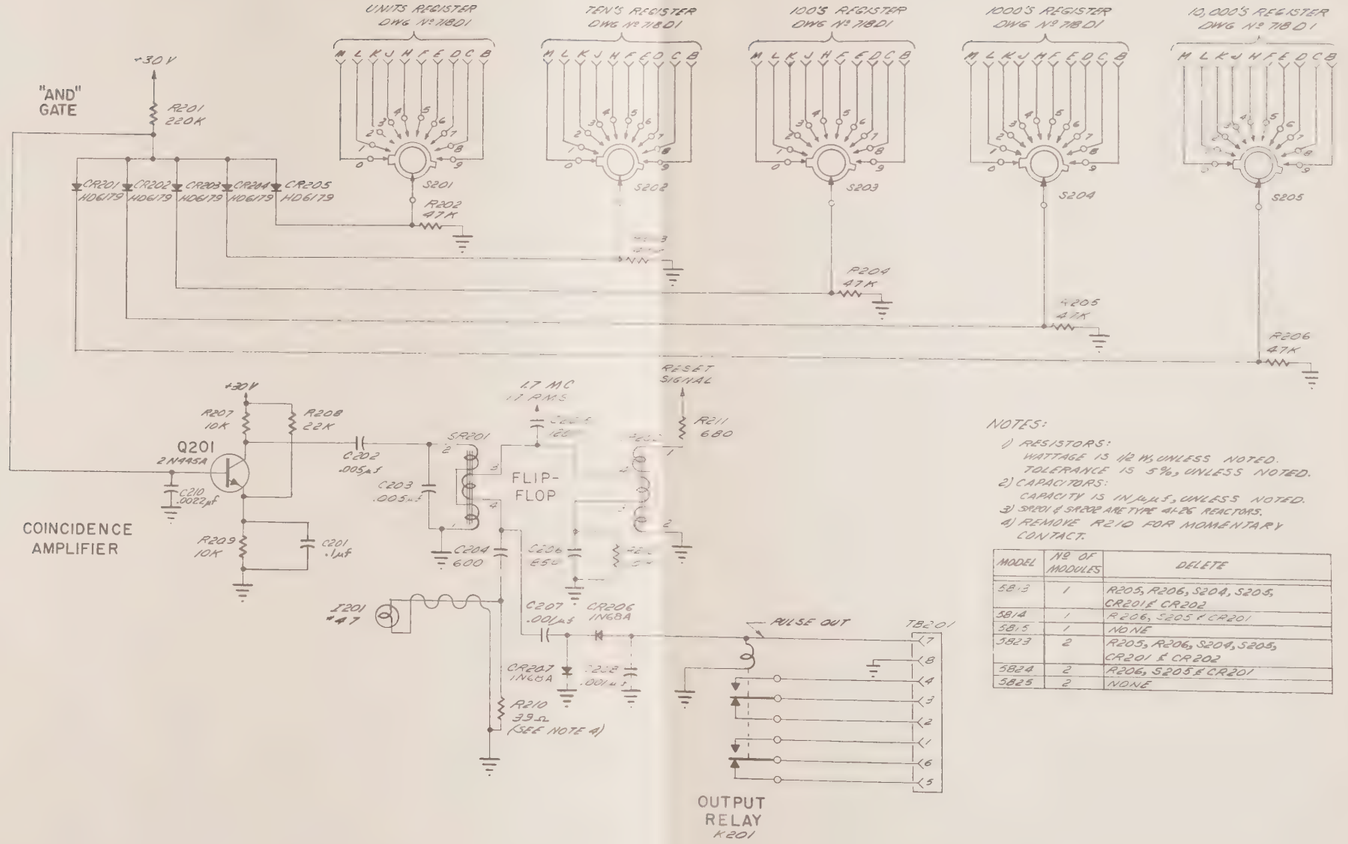
5) DIODES BERKELEY PART NO. B-8300 (IN 95 SELECTED 75 MA. FOWARD CURRENT AT 1 VOLT).

TABULATION

MODEL	DELETE
5803	XAY104, XAY105, R110, R111, C111 & C112
5804	XAY105, R111 & C112
5805	NONE
5813	XAY104, XAY105, R110, R111, C111 & C112
5814	XAY105, R111 & C112
5815	NONE
5823	XAY104, XAY105, R110, R111, C111 & C112
5824	XAY105, R111 & C112
5825	NONE

October 1960

MODEL 5800 SERIES NUMERICAL CONTROLLER
INDICATOR AND POWER SUPPLY
SCHEMATIC DIAGRAM
DWG. NO. 5800 C 1



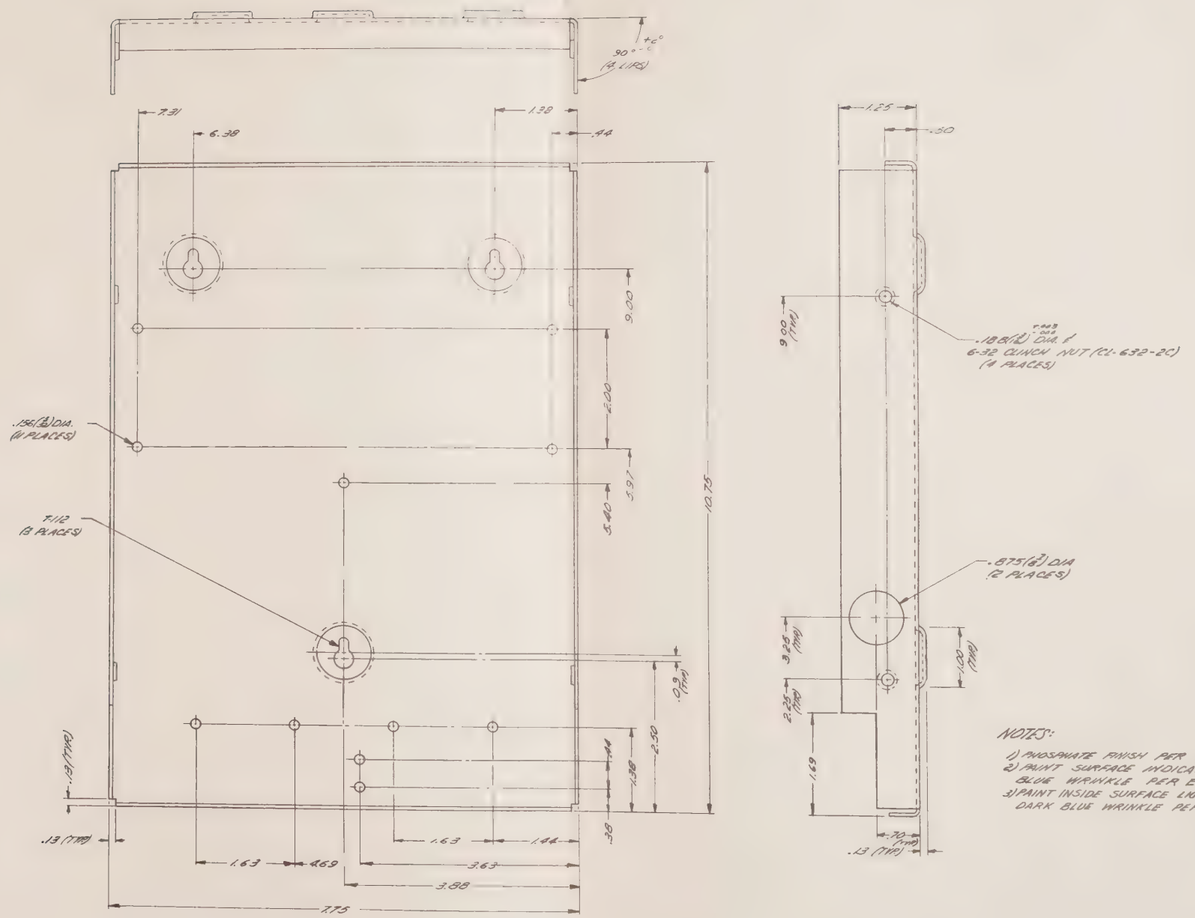
NOTES:

1) RESISTORS:
WATTAGE IS 1/2 W, UNLESS NOTED.
TOLERANCE IS 5%, UNLESS NOTED.
2) CAPACITORS:
CAPACITY IS IN μμf, UNLESS NOTED.
3) SR201 & SR202 ARE TYPE 4AP6 REACTORS.
4) REMOVE R210 FOR MOMENTARY CONTACT.

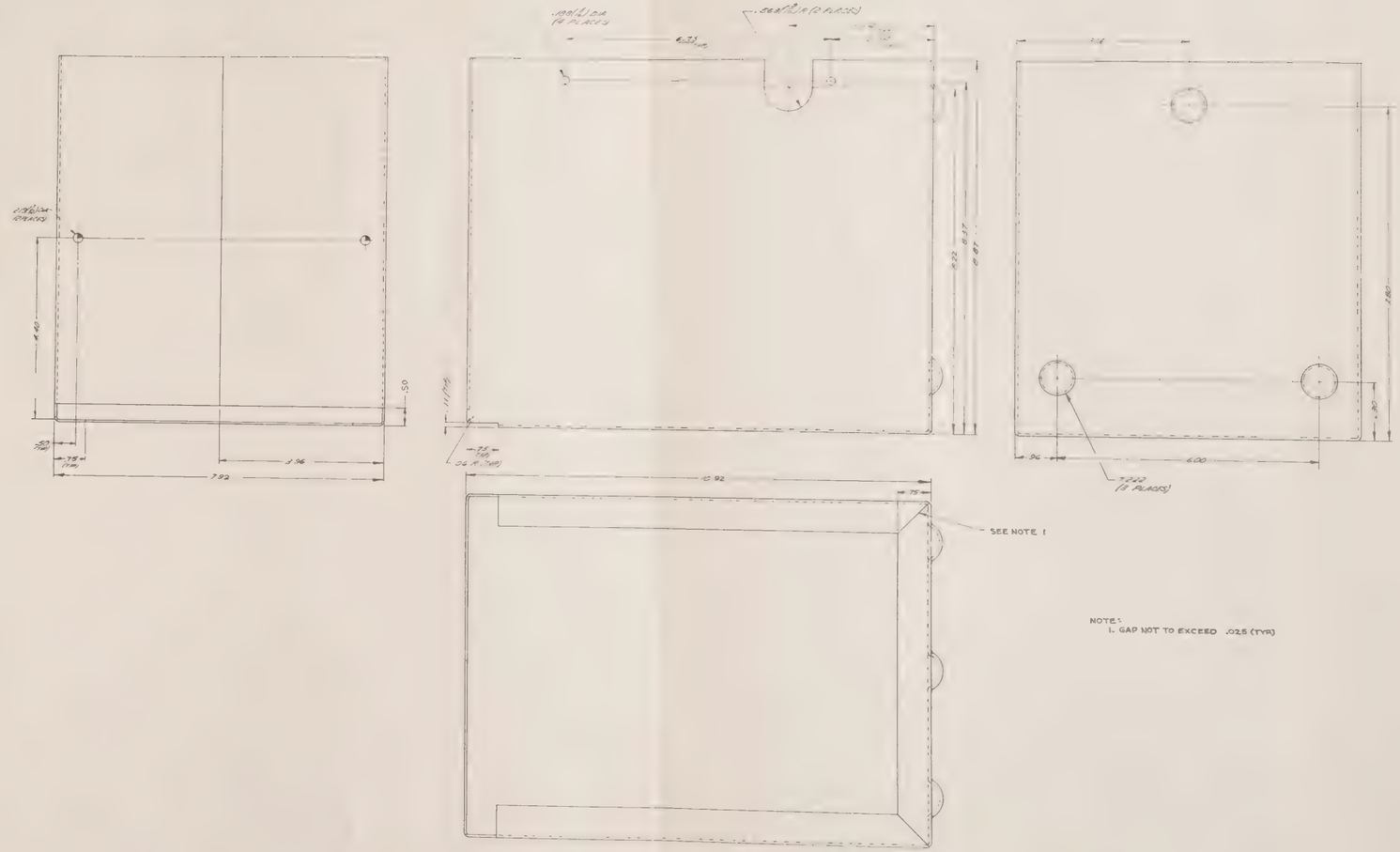
MODEL	NO OF MODULES	DELETE
5813	1	R205, R206, S204, S205, CR201 & CR202
5814	1	R206, S205 & CR201
5815	1	NONE
5823	2	R205, R206, S204, S205, CR201 & CR202
5824	2	R206, S205 & CR201
5825	2	NONE

October 1960

MODEL 5800 SERIES NUMERICAL CONTROLLER
CONTROL MODULE, SCHEMATIC DIAGRAM
DWG. NO. 5800 C 2



MODEL 5800 SERIES NUMERICAL CONTROLLER
MOUNTING DETAILS
DWG. NO. 5800 C 6



MODEL 5800 SERIES NUMERICAL CONTROLLER
CABINET DIMENSIONS
DWG. NO. 5800 D 13

PRELIMINARY
INSTRUCTION MANUAL

MODEL 718
DECIMAL COUNTING UNIT

BECKMAN/ Berkeley Division

Richmond, California
December 1958

WARRANTY

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(a) Some components and accessories by their nature are not intended to, and will not, function one year. If any such component or accessory manufactured by the Company and part of the item sold fails to give reasonable service for a reasonable period of time, the Company will, at its election, replace or repair such component or accessory. What constitutes reasonable service and what constitutes a reasonable period of time shall be determined solely by the Company after the Company is in posession of all the facts concerning operating conditions and other pertinent factors and after such component or accessory has been returned to the Company, transportation prepaid.

(b) All instruments claimed defective must be returned to the Company, transportation charges prepaid, and will be returned to the customer with the transportation charges collect, unless the item is found to be defective in which case the Company will pay all transportation charges.

(c) The Company makes no warranty concerning components or accessories not manufactured by it, such as tubes, fuses, batteries, etc. However, in the event of the failure of any component or accessory not manufactured by the Company, the Company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.

(d) Except as stated above, the Company makes no warranty, express or implied (either in fact or by operation of law), statutory or otherwise; and, except to the extent stated above, the Company shall have no liability under any warranty, express or implied (either in fact or by operation of law), statutory or otherwise.

(e) The Company expressly disclaims any liability to its customers, dealers, and to users of its products, and to any other person or persons for consequential damages of any kind and from any cause whatsoever arising out of or in any way connected with the manufacture, sale, repair, replacement of, or arising out of or in any way connected with the use of any of its products.

(f) Representations and warranties made by any person, including representatives of the Company, which are inconsistent or in conflict with the terms of this warranty (including but not limited to the limitation of the liability of the Company as set forth above) shall not be binding upon the Company unless reduced to writing and approved by an officer of the Company.

(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate. Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, Berkeley division of Beckman Instruments, Inc., Richmond 4, California.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

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BERKELEY DIVISION
BECKMAN INSTRUMENTS, INC.

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Schematic Diagram, Model 718 DCU. Dwg. No. 718 D 1

GENERAL DESCRIPTION

The Model 718 DCU is a direct-reading, printed circuit counting unit which uses a small, encapsulated saturable reactor as its counting element. The unit will count input pulses from zero to nine, returning to zero on the tenth pulse. At each count, the DCU produces an output signal on one of ten corresponding lines. The number of pulses registered is indicated by an illuminated digit. The output signal of one Model 718 will drive another Model 718 DCU. Consequently, these units may be cascaded (that is, the output of one going to the input of the next) to form an electronic counter whose total count capacity depends only on the number of DCU's used. Thus, four units will count to 9,999, resetting to zero on the 10,000th pulse.

TECHNICAL CHARACTERISTICS

Count Indication

Direct-reading decimal display.

Input Requirements

Current pulse, 4 ma peak-to-peak and 3μs to 50μs wide into 60 mh and 680 ohms in series.

Maximum Counting Rate

5000 counts per second.

Resolution of Paired Pulses

200 microseconds.

Output Characteristics

See "Installation".

Reset Requirement

Voltage pulse, ±15v (±20%) amplitude and at least 20 μs duration into 4000 ohms.

Power Requirements

17 volts rms (±10%) at 1.7 mc. (±2%). Consumes 1.5 watts.

Plug-in Connector

15-pin printed card type.

Dimensions

3/4 in. wide, 5 - 1/2 in. high, 3 - 1/4 in. deep.

Weight

6 - 1/2 oz.

INSTALLATION

NOTE: Decimal counting units sold as part of a larger Beckman/Berkeley instrument are fully installed when shipped.

Mounting

The DCU can be mounted by plugging into any 15-pin printed card connector (it must be inserted so that the notch in the card corresponds to terminal N). Although the unit is not particularly affected by stray magnetic fields, a location very close to such things as large motors or transformers should be avoided.

Supplying Power

Connect the 17 volt 1.7 megacycle power source to pin S of the DCU connector.

Input

Connect the source of input pulses to pin R of the DCU connector. The unit will register one count each time the current at this terminal rises from zero to at least 4 ma in either direction and returns to zero (current pulse must be 3μs to 50μs wide). Input impedance is 60 mh in series with 680 ohms.

Output Characteristics

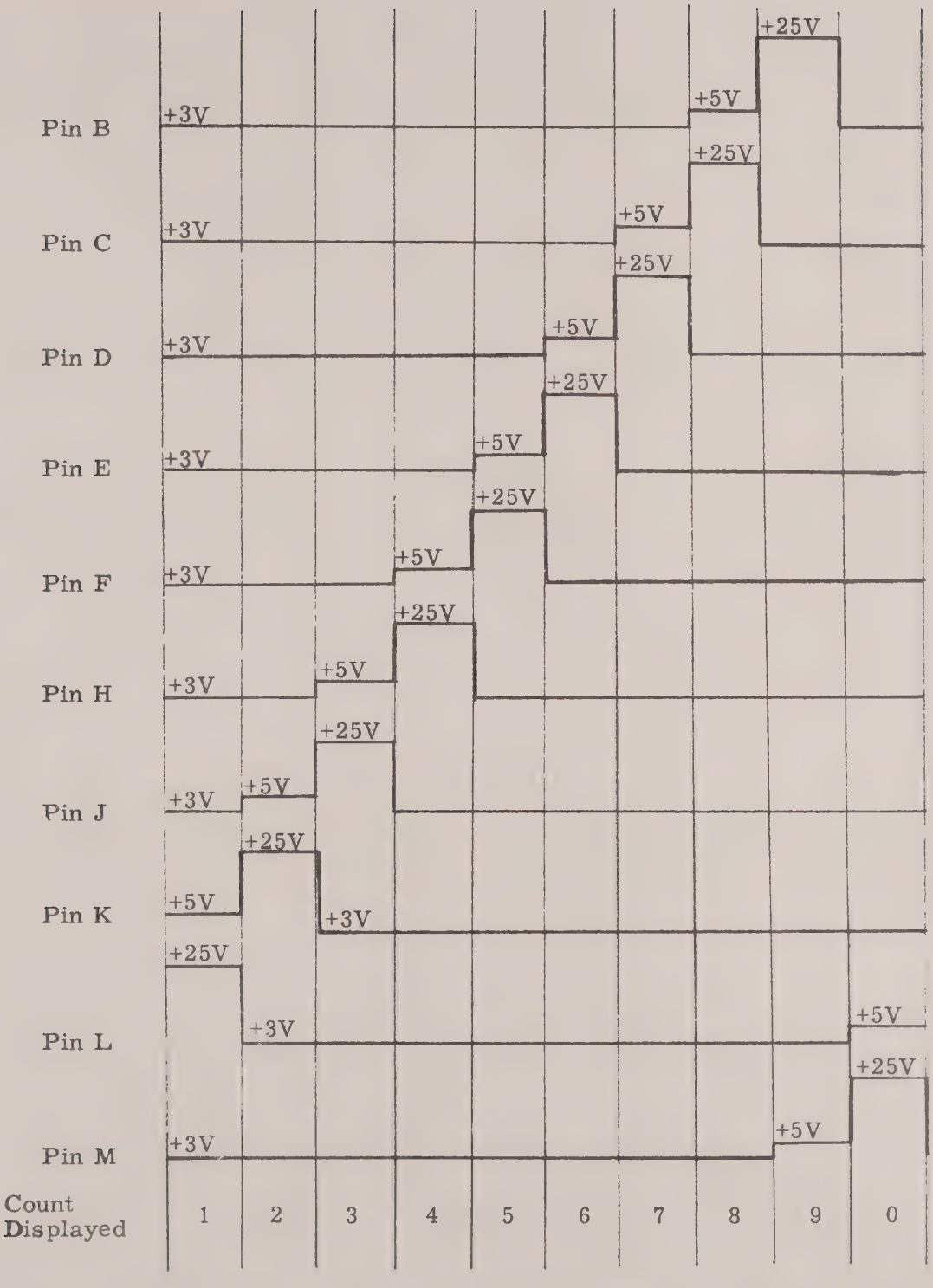
While counting the unit produces output signals at each of the ten terminals B through M. Each of these signals consists of three different voltage levels with respect to ground (pin A), ocurring as shown in Figure 1.

Normally, the +25 volt output at pin M, which occurs each time the indicated count goes from "9" to "0" is used to drive another DCU or some other circuitry. The outputs can be loaded to a maximum steady state current of 3 ma, dropping under this load to +20 volts peak-to-ground.

Capacitance from an output terminal to ground should not exceed 500$\mu\mu$f, resistance to ground should not be less than 5000 ohms.

Resetting to Zero

To reset the unit to zero a voltage pulse must be applied to terminal P of the DCU connector. This pulse must have an amplitude of 15 volts (±20%) into 4000 ohms, and a duration of at least 20 microseconds.



NOTE: Voltages shown are with respect to ground (pin A)

FIG. 1. Output Signals of Model 718 DCU

THEORY OF OPERATION

As shown on drawing 718 D 1, the Model 718 DCU has ten saturable reactors (SR101 through SR110) connected to form a ring counter circuit. This circuit operates very much like that described under "A Ring Counter" in the enclosed section titled "Elementary Circuits Using Saturable Reactors". However, since it uses ten reactors, the unit has ten discrete, stable states.

The circuit is triggered from one state to the next by a momentary reduction in carrier voltage. This occurs whenever an input pulse is applied across the control winding of the triggering reactor (SR111). A pulse of control current causes SR111 to saturate, and the carrier winding circuit to become series resonant. Consequently, the resulting rise in current through the carrier winding of SR111 causes a drop in carrier voltage across all of the saturable reactors.

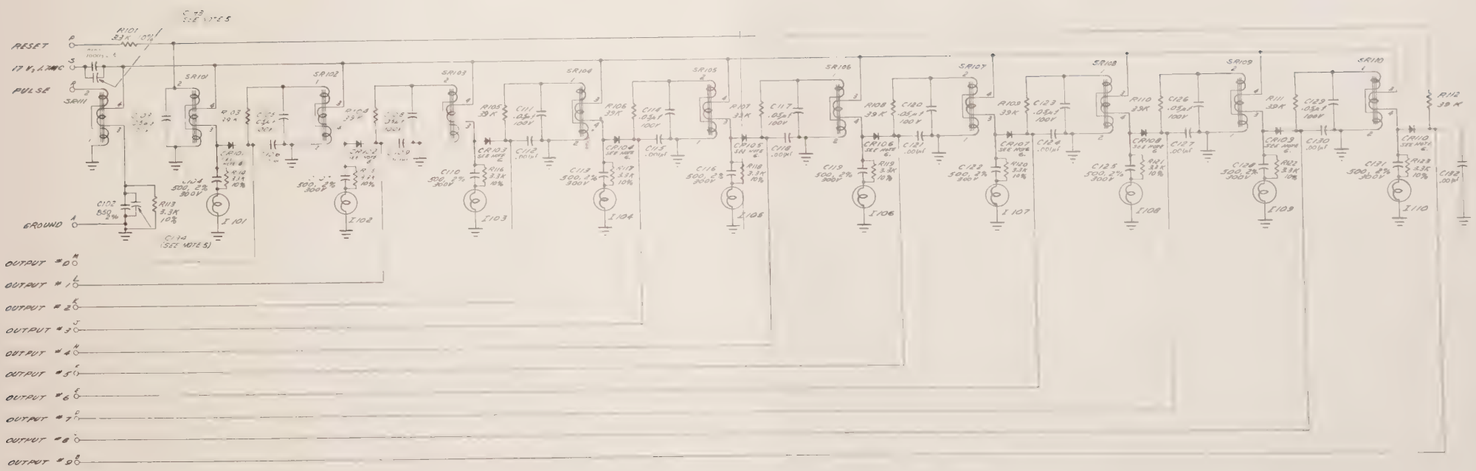
Whenever any one of the ten counting reactors is saturated, the carrier current flowing through its indicator lamp (I101 through I110) illuminates the corresponding digit. The output signal from each reactor is rectified by a crystal diode (CR101 through CR110) and appears at the corresponding output terminal of the unit (see Figure 1).

A reset pulse applied to terminal P of the DCU, draws control current through SR101 and thus causes it to saturate. When SR101 is saturated, the unit registers "0".

MAINTENANCE

It is recommended that field maintenance be confined to replacing defective diodes and indicator lamps. Due to the reliability of magnetic components, other defects will rarely develop. If other faults do occur the DCU should be returned to the Beckman/ Berkeley Division for repairs.

NOTES:
1) RESISTORS:
WATTAGE IS 1/2 W, UNLESS OTHERWISE NOTED.
TOLERANCE IS 5%, UNLESS OTHERWISE NOTED.
2) CAPACITORS:
CAPACITY IS IN μμF, UNLESS OTHERWISE NOTED
3) I 101 THRU I 110 ARE LAMP #328.
4) SR 101 THRU SR 111 ARE 4-176 SATURABLE REACTORS.
5) C 133 & C 134 SELECTED AT FACTORY.
6) DIODES ARE BERKELEY PART NO 8-8300 (MUST BE SELECTED FOR 75MA. FORWARD CURRENT AT 1 VOLT).



December 1960

MODEL 718 DECIMAL COUNTING UNIT
SCHEMATIC DIAGRAM
DWG. NO. 718 D 1

ELEMENTARY CIRCUITS USING SATURABLE REACTORS

THE BASIC AMPLIFIER

Figure 1 is a schematic diagram of a magnetic circuit which is comparable to a vacuum tube amplifier. The magnetic component itself consists of two windings of fine wire on a tiny iron core, all encased in resin. Its basic characteristics arise from the fact that the small core can be saturated by minute currents in either winding. For this reason it is called a "saturable reactor"--abbreviated "SR". With no current the carrier winding has the relatively high inductance of an iron-core inductor. But, when the sum of the currents in both windings increases beyond a certain point, the core saturates and the inductance of the carrier winding falls greatly. When operated as an amplifier, current in the control winding is used to vary the inductance of the carrier winding. If the carrier winding is energized by a carrier supply (an a-c voltage source), its changing inductance will cause changes in the carrier current flowing in it. Since the carrier current variations are much larger than the control current variations, the SR produces amplification. In Figure 1 the a-c carrier current flows through the carrier winding and C1. The voltage developed across C1 is the carrier, modulated in accordance with control current variations. This signal is rectified and filtered to produce a demodulated output.

Notice that this circuit is roughly analogous to a vacuum tube amplifier. Control current corresponds to control grid voltage; carrier supply voltage, to B+ supply; carrier current, to plate current; and load impedance, to plate load. The main differences are that the controlling quantity is a current rather than a potential and that a carrier frequency must be introduced, modulated and finally removed.

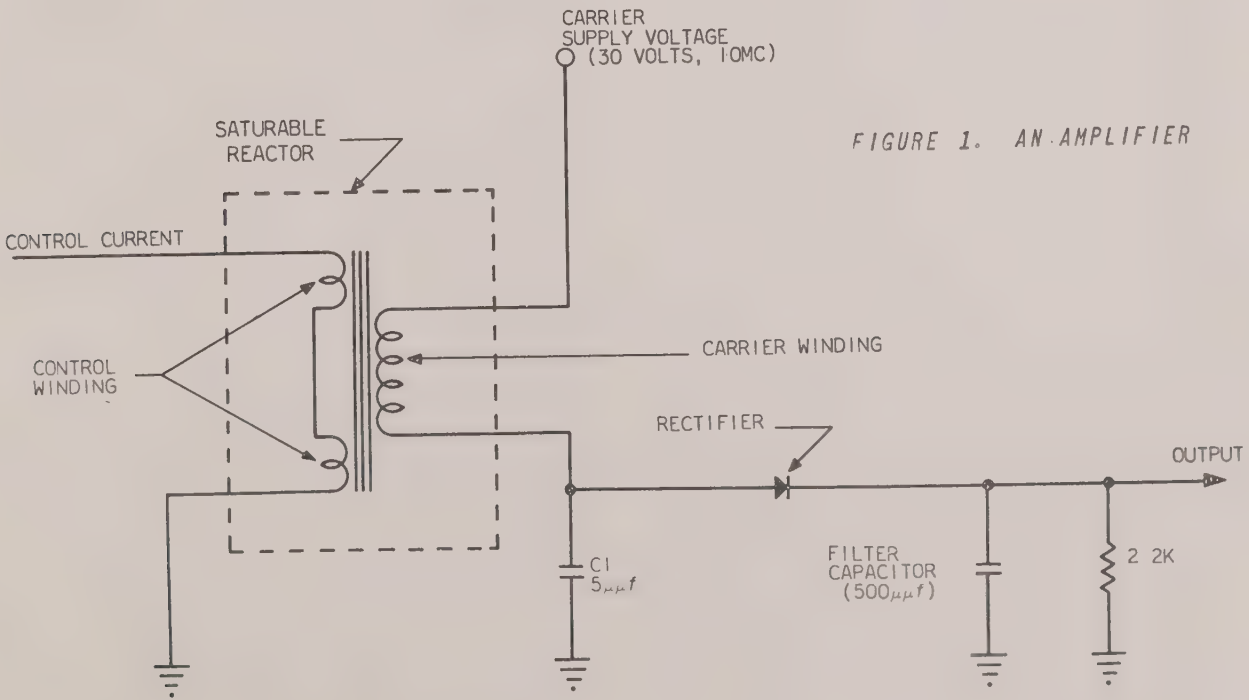


FIGURE 1. AN AMPLIFIER

The transfer characteristics of this amplifier are diagramed in Figure 2. This figure shows how carrier winding inductance and output voltage vary with input current. The inductance is nearly constant from zero current until saturation begins. This range will be called the "non-saturated" region. From the beginning of saturation until the reactor is fully saturated the inductance falls rapidly. This will be called the region of "partial saturation." Beyond full saturation the inductance stays nearly constant again

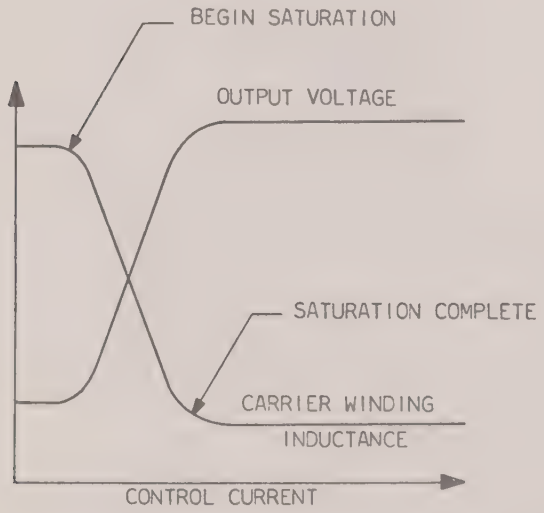


FIGURE 2. AMPLIFIER CHARACTERISTICS

at a lower value. This will be called simply the "saturated" region. Notice that the transfer-characterisitc curve (output voltage VS control current) is analogous to that of a vacuum tube. The point at which saturation begins corresponds to cutoff and the full saturation point corresponds to plate saturation. The gain is apprec - iable only when the control current varies within the region of partial saturation.

A CURRENT DISCRIMINATOR

Figure 3 shows an amplifier circuit which has been converted to a current discriminator by adding positive resistive feedback. This circuit is the magnetic equivalent of the well-known Schmitt trigger vacuum tube circuit. The output voltage E_o draws current through the control winding and feedback resistor in a direction that reinforces the input current. As the input current rises from zero to the point where saturation begins, the output voltage remains almost constant. When the reactor begins to saturate, the gain from input to output rises sharply. At a certain point the feedback loop gain becomes greater than one and the control current and output voltage increase rapidly in a regenerative circuit until the reactor is fully saturated. At this point the gain from input to output decreases again to nearly zero and further increases in input current have no effect. When the input current decreases to a value slightly lower than that at which sudden saturation occurred, the total current in the control winding becomes too low to maintain saturation. At this point the output voltage begins to drop, and a reverse regenerative action returns the circuit to the original unsaturated state. Due to this action the circuit switches rapidly back and forth from one to another of two comparatively constant states as the input current rises and falls. Because the state it assumes depends only upon whether the input current is above or below a certain value, it is called a "current discriminator". The difference between the input current value at which the reactor switches from non-saturation to saturation and the lower value at which it switches back from saturation to non-saturation is called the hysteresis of the circuit. In electronic counters this circuit is used mainly to generate sharp pulses from slowly varying waveforms.

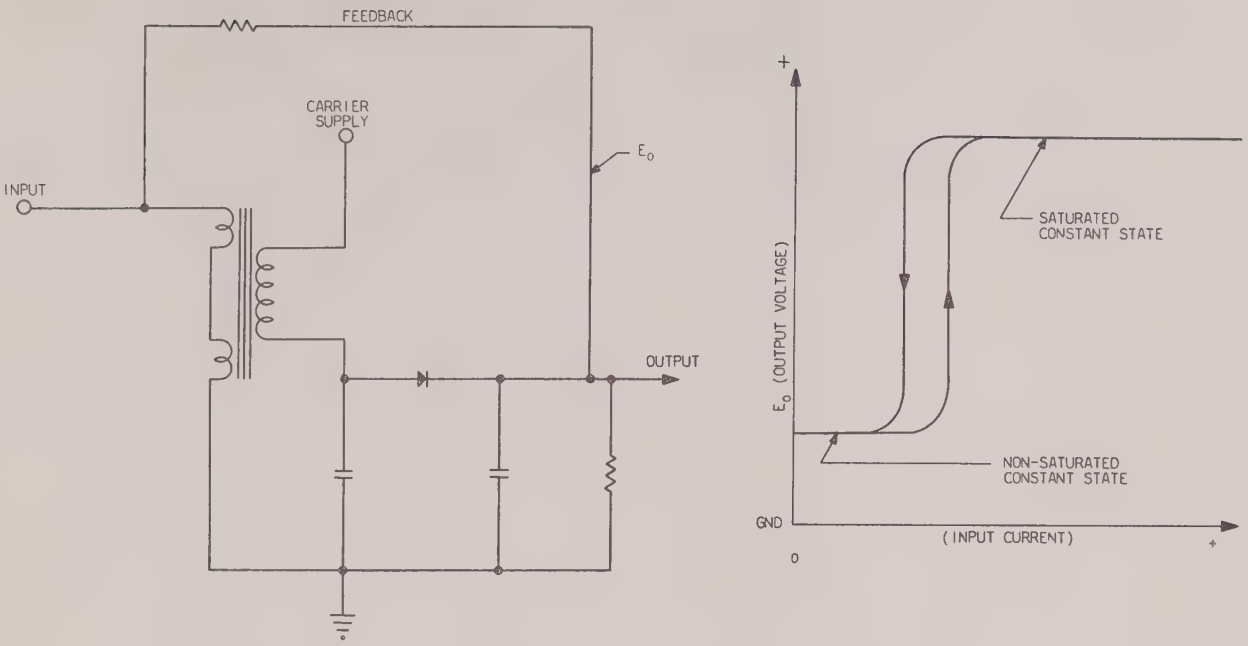


FIGURE 3. A CURRENT DISCRIMINATOR

A CIRCUIT BISTABLE AT ZERO INPUT

If the value of the feedback resistor in the current discriminator described above is lowered, the hysteresis of the circuit will increase until the transfer characteristic curve assumes the shape shown in Figure 4. This happens because the feedback current in the saturated state becomes so great that it will hold the reactor saturated without the aid of any input current, and even when some input current is "bucking" the feedback current in the control winding. In this discussion "positive" input current means current in a direction which aids feedback and "negative" input current means current which "bucks" feedback. Notice that with no input current the circuit is stable in either the saturated or non-saturated state. Due to this characteristic the circuit may be used as a sort of "flip-flop". Starting at zero input current and non-saturation, a pulse of positive current will switch the circuit to saturation, where it will remain when the input returns to zero. With the circuit in the saturated state a pulse of negative input current will switch it back to the non-saturated state, where it will stabilize when the input again returns to zero.

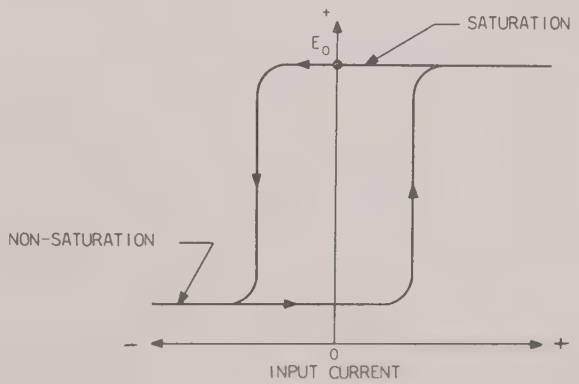


FIGURE 4

A ONE-SHOT MULTIVIBRATOR

Figure 5 shows an amplifier circuit converted to a one-shot multivibrator by adding an R-C feedback loop. The input current to this circuit is usually a series of pulses--in this case, positive pulses. The rising current of each pulse produces a voltage rise at the output. This places a positive potential on the output side of C_f, causing the other side to draw current through R_f and the control winding. If the input pulse has enough amplitude to reach the region of partial saturation, the feedback loop gain will become momentarily greater than one and the conrol current and output voltage will increase rapidly in a regenerative circuit until the reactor is fully saturated. At this point E_o stops rising and the control current decreases as C_f approaches a full charge. When the control current re-enters the region of partial saturation a reverse regenerative action rapidly returns the reactor to the non-saturated state. The duration of full saturation depends upon the R-C time constant of the feedback loop, becoming longer as the time constant lengthens. This circuit is used mainly to produce uniform amplified pulses with steeper leading and trailing edges. It will also function as a pulse gate if a bias current is used to raise and lower the d-c level which the control current assumes in the absence of input pulses. With a high d-c level, input pulses of correct amplitude reach the region of partial saturation and output pulses are produced. In this condition the gate is "open". With a low d-c level, input pulses do not reach partial saturation, no output pulses occur and the gate is effectively "closed".

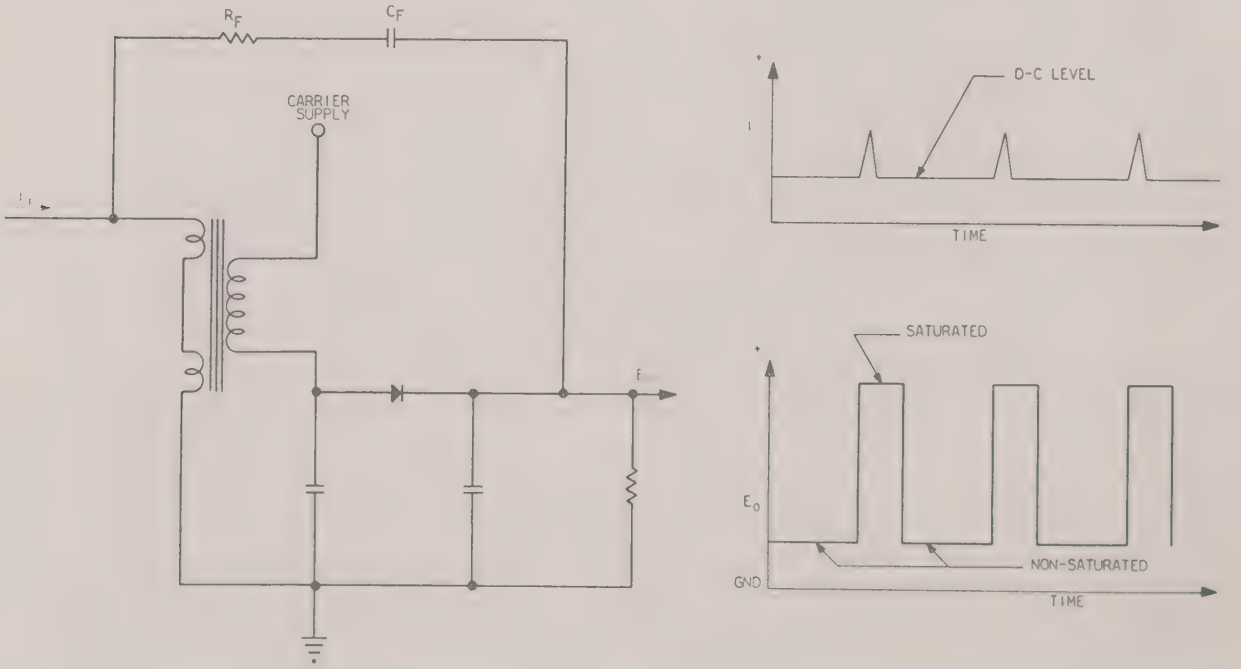


FIGURE 5. ONE-SHOT MULTIVIBRATOR

The amplifier circuits described on the previous pages are built so that the carrier does not have an appreciable saturating effect. This is done by deliberately keeping carrier current comparatively low. However, heavier carrier current can saturate the reactor without the aid of any control current. Consider the circuit shown in Figure 6, C1 has a value such that its capacitive reactance equals the inductive reactance of the carrier winding (L1) at some point near full saturation. At this point the carrier winding circuit becomes series resonant and its total impedance becomes so small that enough carrier current flows to saturate the reactor in the absence of control current.

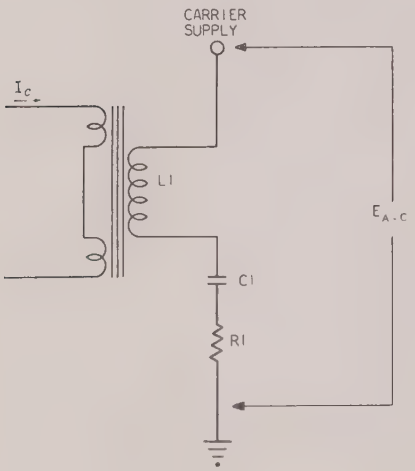


FIGURE 6.

Figure 7 shows how the reactance of the carrier winding circuit varies with carrier current (I_{a-c}) when there is no control current (I_c) whatever. Current and reactance are interdependent. Up to the resonant point an increase in current causes a decrease in reactance which causes a further increase in current producing another decrease in reactance, etc. This mutual reinforcement creates the possibility of a "run-away" regenerative action. When E_{a-c} is initially applied, the current rises and the reactance falls to point B. At this point the circuit stabilizes because increasing current does not cause the reactance to fall rapidly enough to create a "run-away" effect. However, if the reactance is lowered to point C by some device, "run-away" regeneration will occur and the carrier current will increase through the resonant point and beyond. At point F the circuit will stabilize again since the reactance (now capacitive) is increasing with further increases in I_{a-c}. Thus, the circuit has two stable states: a non-saturated state at point B and a saturated state at point F. The circuit may be triggered from non-saturation to saturation by any action which will partially saturate the reactor enough to lower the reactance to point C. To switch the circuit back to the non-saturated state the carrier voltage must be lowered enough so that too little current will flow to maintain saturation even at the resonant point.

Figure 8 shows the relationship between the voltage across the carrier winding circuit (E_{a-c}) and the current flowing (I_{a-c}) when the load resistance (R1) is taken into account. This diagram illustrates the bistable characteristics of the circuit well. Note that at a certain operating voltage either of two possible values of current can exist: one at point B (non-saturated) and one at point F (saturated). Point D, in the "negative resistance" part of the curve is highly unstable.

Two methods are used to switch the circuit from one stable state to the other. One is to change the operating voltage (E_{a-c}) momentarily. Suppose the circuit is stable at point B. If E_{a-c} is raised to a value above that at point C the current will jump to some value beyond point G. If E_{a-c} is then returned to the bistable operating

voltage the current will decline to the other stable value at point F. On the other hand, if the current is stable at point F and E_{a-c} is reduced to a value below that at point E, the current will drop swiftly to a value below that at point A. If E_{a-c} is then returned to the bi-stable voltage the current will rise to a stable value at point B.

Applying a surge of control current is another way of switching the circuit from one stable state to the other. The total reactance curve shown in Figure 7 is that obtained without control current. If some d-c control current is applied the reactance curve will be shifted to the left as shown in Figure 9. This occurs because the control current now assists the a-c current in producing saturation. Consequently, the carrier winding circuit will reach the point of resonance at a lower value of a-c current. Figure 10 shows the resultant relationship between E_{a-c} and I_{a-c} when control current flows. Note that the circuit is no longer bi-stable at the operating voltage shown in Figure 8. At this voltage it is stable only in the saturated state. If the circuit is operating at point B in Figure 8, a surge of control current will switch it to the saturated state. When the control current declines again to zero the circuit will stabilize at operating point F. Notice, however, that a pulse of control current will not switch the circuit from the saturated state to the non-saturated state.

R1 in Figure 6 was placed in series with L1 and C1 to simplify the circuit. In practice the load resistance is usually connected in parallel with C1. This arrangement will produce the same effect described above if the parallel resistance has the proper value.

REFERENCES

For more thorough descriptions of magnetic circuits see the articles listed below.

(1) "Ferroresonant Flip -Flops" Carl Isborn, Electronics, April 1952.

(2) "An Unstable Nonlinear Circuit" Claude Summers, Elect. Engr., May 1940.

(3) "Critical Conditions in Ferroresonance", P. H. Odessey and E. Weber, AIEE Transactions V. 57, p. 444, Aug. 1938.

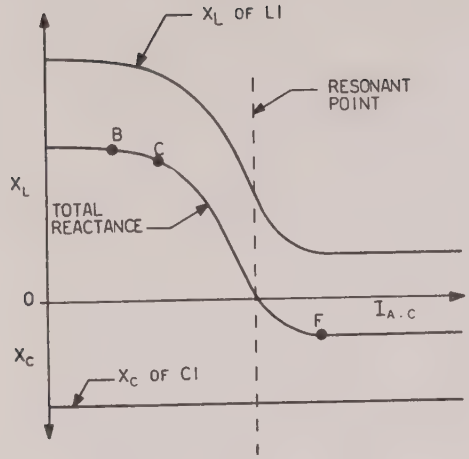
(4) "Non-Linear Circuits Applied to Relays" C. G. Suits, Elect. Engr. April 1933.

(5) "Non-Linear Circuits for Relay Applications" C. G. Suits, Elect. Engr., Dec. 1931.

(6) "Resonant Non-Linear Control Circuits" W. T. Thomson, AIEE Transactions, Aug. 1938.

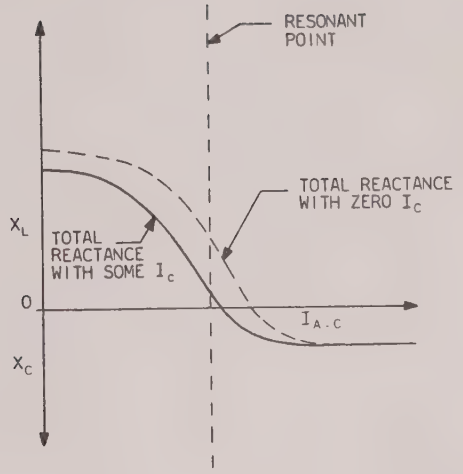
(7) "Resonant Theory Series Non-Linear Circuits" E. G. Keller, Journal of Franklin Institute, May 1938.

(8) "Studies in Non-Linear Circuits" C.G. Suits, AIEE Transactions, June 1931.



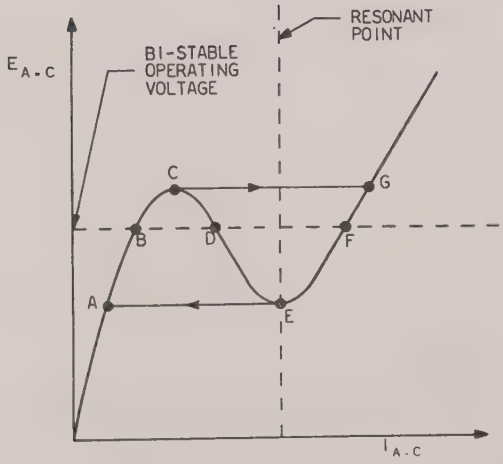
I_{A-C} VS REACTANCE AT ZERO I_C

FIGURE 7.



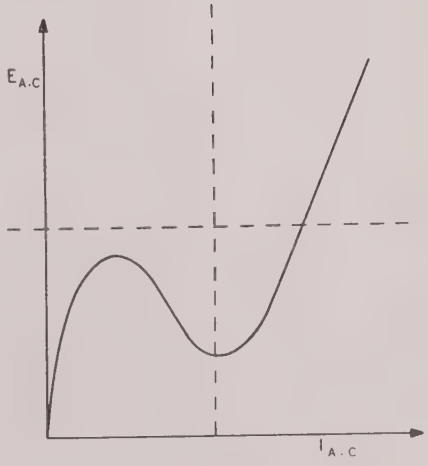
I_{A-C} VS REACTANCE WITH SOME I_C

FIGURE 9.



E_{A-C} VS I_{A-C} AT ZERO I_C

FIGURE 8.



E_{A-C} VS I_{A-C} WITH SOME I_C

FIGURE 10.

A RING COUNTER

Method of Obtaining Discrete Stable States. Several of the bistable circuits described under "FERRORESONANCE" can be connected in a ring to form a pulse counting device. Figure 11 shows a ring circuit made up of three saturable reactors which, consequently, has three discrete stable states. It is called a ring-of-three. The carrier winding circuits are connected in parallel to the carrier supply through a high impedance (C1). Only one reactor can be saturated at any given time for the following reason. If C1 were shorted, the voltage across all bistable combinations would rise high enough to cause all the reactors to saturate with carrier current alone. However, since carrier voltage is applied through C1, the voltage across all bistable combinations initially rises only until one reactor saturates and draws heavy current through its carrier winding. When this happens the voltage across all three is lowered due to the voltage drop across C1. The lowered voltage is high enough to maintain saturation in one reactor but not high enough to cause either of the other two to saturate if unaided by control current.

Referring to Figure 8, the voltage across one bistable combination originally rises to that at point C, then falls to a value between that at point C and that at point E. If more than one reactor began to saturate, the voltage across all would drop below the value at point E, and all but one would be forced into the non-saturated state. This circuit is analogous to three gas tubes connected in parallel to a d-c voltage through a high impedance. When voltage is applied, the potential across the tubes rises until one breaks down. Once this occurs the other tubes will not fire because their ionizing voltage is greater than the operating voltage of the tube already conducting.

Triggering the Ring Counter. One method of triggering the ring from one state to another is to lower the carrier voltage momentarily. Figure 11 shows a circuit designed to be triggered this way. Suppose SR2 is the saturated reactor. Then the high r-f output voltage at the junction of SR2 and C4 charges C5 through diode CR1. The lower r-f voltage at the outputs of SR3 and SR4 produces only a small charge on C8 and C11.

With the circuit in this condition, a current pulse is applied to the input. The current flowing through the control winding of SR1 lowers the reactance of its carrier winding to the point at which the inductance of SR1 and capacitance of C2 become series resonant. This lowers the voltage on the RF bus to such a value that SR2 is forced out of the saturated state. (Note that R2 keeps SR1 and C2 from latching in the high current condition.)

At the end of the input pulse, the voltage on the RF bus again rises until one of the reactors saturates. In this case, SR3 saturates first because it is already partially saturated by current flowing in its control winding as C6 discharges. The next input pulse returns SR3 to the non-saturated state and saturates SR4. Successive input pulses cause the saturated state to revolve around the ring in such a way that the lamps (I1, I2 and I3) indicate the number of pulses counted.

Rings-of-ten can be cascaded to provide decimal counters of any capacity.

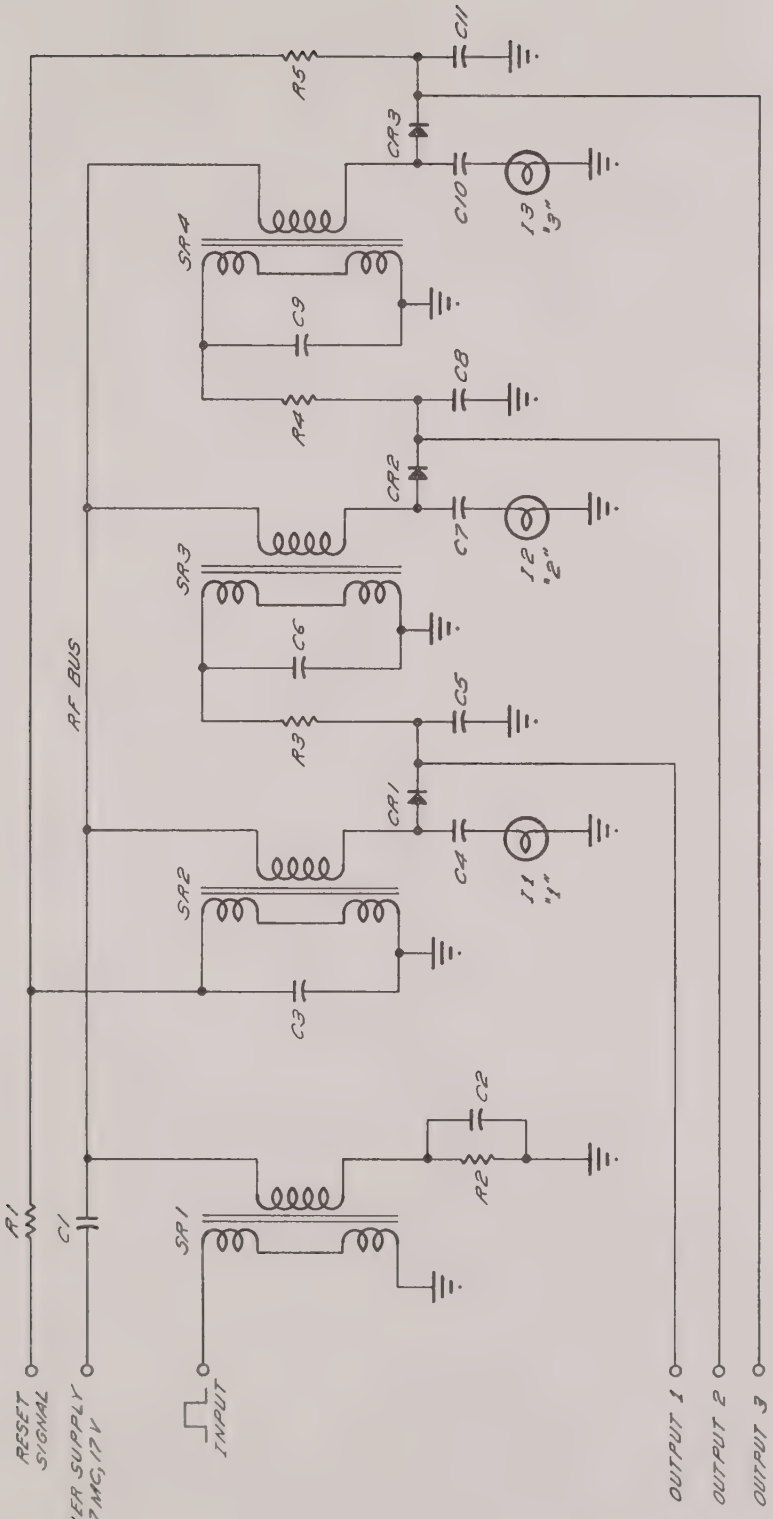
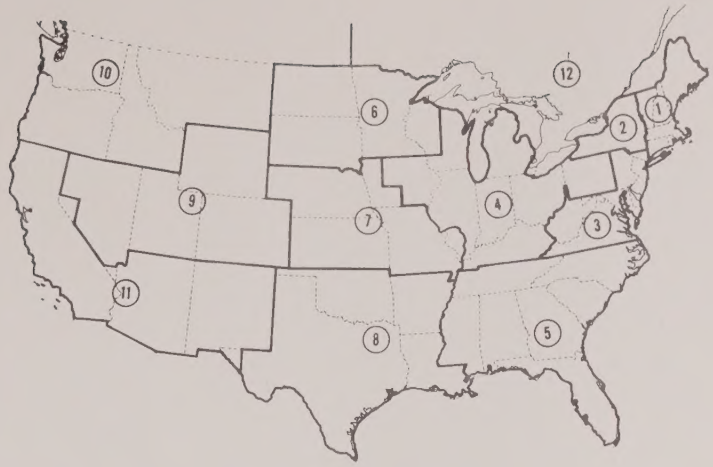


FIGURE 11. A RING-OF-THREE (WITH TRIGGERING SR)



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